Simulation of fatigue crack growth in heterogeneous material with Peridynamics

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Abstract

Cracks are present in almost all structural components. It is of the highest importance to be able to describe fatigue crack propagation in engineering structures for a safe use and to define a proper repair and maintenance program. Even though a large amount of analytical work has been performed, the description of the behaviour of actual component geometries under realistic loading conditions require the use of numerical methods. The modeling of damage propagation phenomena is usually a difficult task because it is necessary to have the capability of describing generation and growth of material discontinuities. In the last thirty years, several approaches have been developed to model and simulate fatigue crack growth in structural components such as the boundary element method [1], the finite element method [2], mesh free methods [3], the extended finite element method [4] and the free Galerkin method [5]. In these approaches, it is necessary to define a criterium to predict the direction of crack growth and the evaluation of the stress intensity factor is needed to estimate the expected crack advance length.

Recently, a powerful method based on a new non-local continuum theory, Peridynamics [6], has been introduced. A distinguishing feature of this approach is its ability to treat the spontaneous formation of discontinuities at different locations together with their mutual interaction and growth in a consistent framework. The method does not require separate crack growth laws to be provided for crack and damage initiation, growth, arrest, branching and so on: these features emerge from the equation of motion and constitutive models. A body can be discretized as a set of material points mutually interacting within a finite distance. This interaction (bond) can be modeled as an elastic, possibly nonlinear, spring. A bond can be broken when its elongation exceeds a critical value depending on the material properties. A wide variety of problems can be solved with a peridynamic approach ([7-9]). But only recently the peridynamic formulation has been enriched by introducing a damaging effect due to the high cycle fatigue phenomena. At least two strategies can be adopted: damage accumulation can be considered as a cycle dependent reduction of bond stiffness [10] or as a degradation of the failure stretch [11]. The main parameters of the fatigue damage model are the material fatigue parameters and the number of the load cycles. In this paper the peridynamic method will be applied to model a 2D structure in presence of voids, inclusions and cracks randomly distributed under high cycle fatigue load conditions. Results will be evaluated taking into account different mesh sizes, horizon dimensions, crack initial lengths and crack orientations.
References


